

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
22 May 2003 (22.05.2003)

PCT

(10) International Publication Number
WO 03/042258 A1

(51) International Patent Classification⁷: **C08F 10/08**,
4/642

(21) International Application Number: PCT/EP02/12731

(22) International Filing Date:
8 November 2002 (08.11.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
012 04 317.0 12 November 2001 (12.11.2001) EP

CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,
GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC,
LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW,
MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG,
SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ,
VN, YU, ZA, ZM, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE,
ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK,
TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, ML, MR, NE, SN, TD, TG).

(71) Applicant (for all designated States except US): **BASELL
POLYOLEFINE GMBH** [DE/DE]; Brühler Strasse 60,
50389 Wesseling (DE).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **RESCONI, Luigi**
[IT/IT]; Via Arianuova, 56/B, I-44100 Ferrara (IT).

(74) Agent: **COLUCCI, Giuseppe**; Basell Poliolefine Italia
S.P.A., Intellectual Property, P.le G. Donegani 12, 44100
Ferrara (IT).

(81) Designated States (national): AE, AG, AL, AM, AT, AU,
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,

Declarations under Rule 4.17:

- as to the applicant's entitlement to claim the priority of the
earlier application (Rule 4.17(iii)) for all designations
- of inventorship (Rule 4.17(iv)) for US only

Published:

- with international search report
- before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments

For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.



WO 03/042258 A1

(54) Title: PROCESS FOR POLYMERIZING 1-BUTENE AND 1-BUTENE POLYMERS

(57) Abstract: A process for polymerizing 1-butene, optionally with up to 30% by mol of ethylene, propylene or an alpha olefin of formula $\text{CH}_2=\text{CHT}$ wherein T is a $\text{C}_3\text{-C}_{10}$ alkyl group, in the presence of a catalyst system obtainable by contacting a metallocene compound having C_1 symmetry with an alumoxane and/or a compound capable of forming an alkyl metallocene cation.

PROCESS FOR POLYMERIZING 1-BUTENE AND 1-BUTENE POLYMERS

The present invention relates to a process for polymerizing 1-butene by using metallocene compounds and to the isotactic polybutene obtained thereby.

1-Butene polymers are well known in the art. In view of their good properties in terms of pressure resistance, creep resistance, and impact strength they have a lot of uses such as the manufacture of pipes to be used in the metal pipe replacement, easy-open packaging and films.

The 1-butene (co)polymers are generally prepared by polymerizing 1-butene in the presence of TiCl_3 based catalysts components together with diethylaluminum chloride (DEAC) as cocatalyst. In some cases diethyl aluminum iodide (DEAI) is also used in mixtures with DEAC. The polymers obtained, however, generally do not show satisfactory mechanical properties. Furthermore, in view of the low yields obtainable with the TiCl_3 based catalysts, the 1-Butene polymers prepared with these catalysts have a high content of catalyst residues (generally more than 300 ppm of Ti) which lowers the properties of the polymers making it necessary a deashing step.

1-butene (co)polymers can also be obtained by polymerizing the monomers in the presence of a stereospecific catalyst comprising (A) a solid component comprising a Ti compound and an electron-donor compound supported on MgCl_2 ; (B) an alkylaluminum compound and, optionally, (C) an external electron-donor compound. A process of this type is disclosed in EP-A-172961 and more recently in WO99/45043.

In *Macromolecules* 1995, 28, 1739-1749 *rac*-dimethylsilylbis(4,5,6,7-tetrahydro-1-indenyl)zirconium dichloride and methylaluminumoxane have been used for polymerizing 1-butene, even if the yield of the process is not indicated the molecular weight of the polymer (M_n) is very low.

Recently metallocene compounds have been used for producing 1-butene polymers. In *Macromol. Rapid Commun.* 18, 581-589 (1997) *rac* and *meso*-[dimethylsilylenebis(2,3,5-trimethyl-cyclopentadienyl)]zirconium dichloride have been used for the polymerization of 1-butene. The yields of the process and the molecular weight of the obtained polymers are rather low.

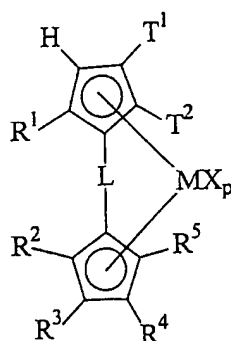
More recently in *Macromolecules* 2000, 33, 1955-1956, $\text{Me}_2\text{Si}(2\text{-Me-4,5-BzoInd})_2\text{ZrCl}_2$, $\text{Me}_2\text{Si}(2\text{-Me-4-PhInd})_2\text{ZrCl}_2$ and $\text{Me}_2\text{Si}(\text{Ind})_2\text{ZrCl}_2$ have been tested in the polymerization of 1-butene. Even if the molecular weights of the polymers appear to be quite high, the activities of these catalysts are low as shown in the comparative examples of the present application.

In WO 02/16450 it is described a 1-butene polymer endowed with a low isotacticity. This polymer is obtained by using a specific class of metallocene compounds having a double bridge. With the process of the present invention it is possible to obtain 1-butene polymers having a higher value of isotacticity or that do not meet all the parameters disclosed in this PCT application, by using completely different metallocene compounds.

A new process that permits to obtain 1-butene polymers with high molecular weight and in high yield is therefore desirable.

Thus, according to a first aspect, the present invention relates to a process for polymerizing 1-butene comprising contacting under polymerization conditions 1-butene, optionally from 0 to 30% by mol; preferably from 0 to 10% by mol of ethylene, propylene or an alpha olefin of formula $\text{CH}_2=\text{CHT}$ wherein T is a $\text{C}_3\text{-C}_{10}$ alkyl group, in the presence of a catalyst system obtainable by contacting:

(A) a metallocene compounds belonging to the following formula (I):



(I)

wherein:

M is an atom of a transition metal selected from those belonging to group 3, 4, or to the lanthanide or actinide groups in the Periodic Table of the Elements (new IUPAC version); preferably M is zirconium titanium or hafnium;

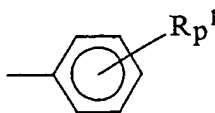
X, equal to or different from each other, is a hydrogen atom, a halogen atom, a R, OR, OR'O, OSO_2CF_3 , OCOR , SR, NR_2 or PR_2 group wherein R is a linear or branched, saturated or unsaturated $\text{C}_1\text{-C}_{20}$ -alkyl, $\text{C}_3\text{-C}_{20}$ -cycloalkyl, $\text{C}_6\text{-C}_{20}$ -aryl, $\text{C}_7\text{-C}_{20}$ -alkylaryl or $\text{C}_7\text{-C}_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; R' is a $\text{C}_1\text{-C}_{20}$ -alkylidene, $\text{C}_6\text{-C}_{20}$ -arylidene, $\text{C}_7\text{-C}_{20}$ -alkylarylidene, or $\text{C}_7\text{-C}_{20}$ -arylalkylidene radical; preferably X is a hydrogen

atom, a halogen atom, a OR'O or R group; more preferably X is chlorine or a methyl radical;

p is 1 or 2 being equal to the oxidation state of the metal M minus 2;

R¹ is a hydrogen atom or a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

R² with R³, and R⁴ with R⁵, form a 5 or 6 membered unsaturated rings, preferably said rings are aromatic, optionally said rings contain heteroatoms belonging to groups 13 -16 of the Periodic Table of the Elements, and optionally said rings bear alkyl substituents, preferably said alkyl substituents are C₁-C₁₀-alkyl radicals;



T¹ is C(R⁶)₃ or

wherein R is a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; p¹ is an integer ranging from 0 to 5; R⁶, equal to or different from each other, are hydrogen atoms or a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; with the proviso that at least one R⁶ is different from hydrogen atom;

T² is a hydrogen atom or a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

or T¹ and T² can also join to form a saturated or unsaturated, condensed 5 or 6 membered ring optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements; said ring can be substituted, preferably the substituents are C₁-C₂₀ alkyl groups optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements; to form for example a condensed benzene ring; a condensed thiophene ring; a condensed pyrrole ring;

L is a divalent bridging group selected from the group consisting of CR^7_2 , SiR^7_2 , $(CR^7_2)_2$ and $(SiR^7_2)_2$ radicals, wherein R^7 , equal to or different from each other, are hydrogen atoms or a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; optionally two R^7 groups can also form an aliphatic ring having 3 to 8 atoms which can bear alkyl substituents, preferably said alkyl substituents are C_1 - C_{10} -alkyl radicals; L is preferably CR^7_2 or SiR^7_2 ; preferably R^7 is a hydrogen atom or a methyl or phenyl radical; more preferably L is $Si(CH_3)_2$ or $C(CH_3)_2$;

(B) an alumoxane or a compound capable of forming an alkyl metallocene cation; and optionally

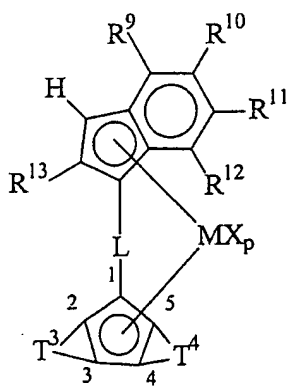
(C) an organo aluminum compound.

Non limiting examples of rings formed by R^2 and R^3 or R^4 and R^5 are condensed benzene rings; condensed thiophene rings; and condensed pyrrole rings;

Preferred metallocene compounds of formula (I) belongs to the following three classes (1), (2) and (3) and have respectively formula (II), (III) and (IV).

Class (1)

Metallocene compounds belonging to class (1) have the following formula (II)



(II)

wherein:

L, M, X and p have the same meaning as described above;

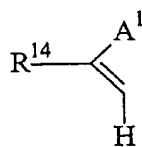
R^{13} is a hydrogen atom or a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl,

C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably R¹³ is a linear or branched C₁-C₂₀ alkyl radical; more preferably R¹³ is a methyl or an ethyl radical;

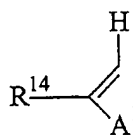
R⁹, R¹⁰, R¹¹ and R¹² are hydrogen atoms or linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radicals, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; R⁹, R¹⁰, R¹¹ and R¹² can also form one or more 5 or 6 membered saturated or unsaturated rings optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements, said rings can bear alkyl substituents;

preferably R⁹ is selected from the group consisting of C₁-C₂₀ alkyl and C₆-C₂₀ aryl radicals, even more preferably R⁹ is a methyl, tertbutyl, isopropyl, phenyl, alkyl substituted phenyl radical; preferably said alkyl substituents are C₁-C₁₀-alkyl radicals; preferably R¹⁰, R¹¹ and R¹² are hydrogen atoms;

T³ and T⁴ are moieties of formula (IIa) or (IIb):



(IIa)



(IIb)

wherein:

when T³ and T⁴ are moieties of formula (IIa) A¹ bonds to the cyclopentadienyl group in position 2 and 5;

when T³ and T⁴ are moieties of formula (IIb) A¹ bonds to the cyclopentadienyl group in position 3 and 4;

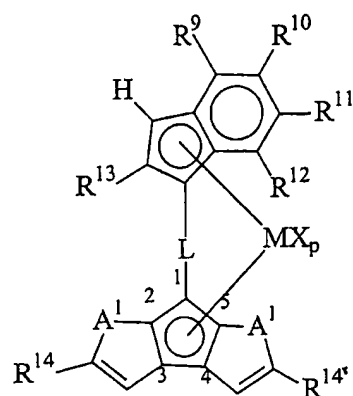
A¹ is a sulphur atom (S), a oxygen atom (O), or a NR, PR, or CR¹⁵ group; wherein R is a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; and R¹⁵ is a hydrogen atom or a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably in the moiety (IIa) A¹ is sulfur and in the moiety (IIb) A¹ is NR; preferably the group NR is N-methyl, N-ethyl or N-phenyl

radical; preferably R^{15} is a hydrogen atom;

R^{14} is a hydrogen atom or a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably R^{14} is a C_1 - C_{20} alkyl radical; more preferably R^{14} is a methyl radical;

preferably T^3 and T^4 are moieties of formula (IIa);

preferred compounds of formula (II) has formula (IIc)

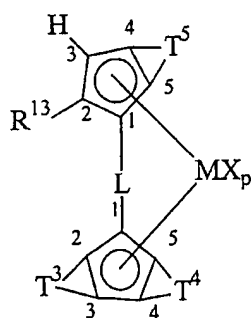


(IIc)

wherein R^9 , R^{10} , R^{11} , R^{12} , R^{13} , R^{14} , A^1 , L , M , X , and p have the same meaning as described above.

Class (2)

Metallocene compounds belonging to class (2) have the following formula (III)

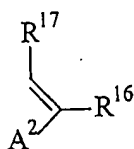


(III)

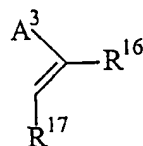
wherein:

T^3 , T^4 , R^{13} , M , X , p and L have the same meaning as described above;

T^5 is a moiety of formula (IIIa) or (IIIb)



(IIIa)



(IIIb)

wherein:

in the moiety of formula (IIIa) A² bonds to the cyclopentadienyl group in position 5; in the moiety of formula (IIIb) A³ bonds to the cyclopentadienyl group in position 4;

A² is a sulfur atom (S), an oxygen atom (O), or a CR¹⁵ group; wherein R¹⁵ is defined as above; preferably A² is a sulphur atom;

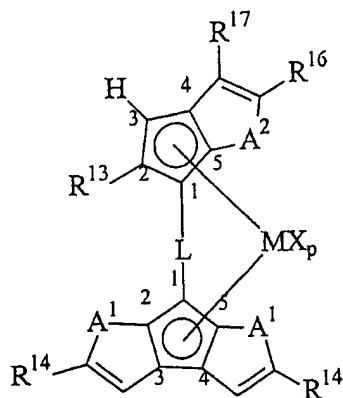
R¹⁶ is a hydrogen atom or a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably R¹⁶ is a C₁-C₂₀ alkyl radical; more preferably R¹⁶ is a methyl radical;

R¹⁷ is a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; R¹⁷ and R¹⁶ can also join to form a 5 or 6 membered aliphatic or aromatic ring; said ring can bear alkyl substituents, preferably said alkyl substituents are C₁-C₁₀-alkyl radicals;

preferably R¹⁷ is a C₁-C₂₀ alkyl or C₆-C₂₀ alkylaryl radical; more preferably R¹⁷ is phenyl radical substituted with one or more C₁-C₂₀ alkyl radical; preferably the substitution is in position 2 or 2 and 4 with respect to the phenyl ring;

A³ is a NR group or a CR¹⁵ group wherein R is a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; and R¹⁵ is defined as above; preferably A³ is a NR group; more preferably A³ is a N-methyl or N-phenyl group.

Particularly preferred are those compounds wherein T⁵ is a moiety of formula (IIIa) and T³ and T⁴ are moieties of formula (IIa) to form a compound of formula (IIIc)

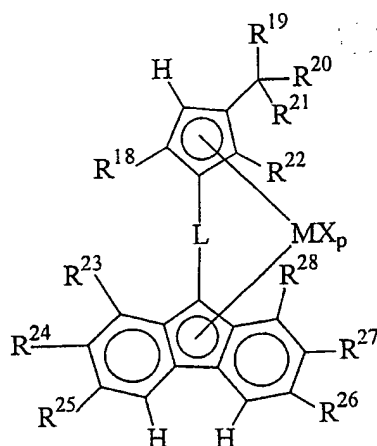


(IIIc)

wherein R^{13} , R^{14} , R^{16} , R^{17} , A^1 , A^2 , L , M , X , and p have been described above.

Class (3)

Metallocene compounds belonging to class (3) have the following formula (IV)



(IV)

Wherein M , L , X and p have the same meaning as described above;

R^{18} , R^{22} , R^{23} , R^{24} , R^{25} , R^{26} , R^{27} and R^{28} are hydrogen atoms or a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; or two or more adjacent R^{23} , R^{24} , R^{25} , R^{26} , R^{27} , and R^{28} can form one or more aliphatic or aromatic C_4 - C_8 rings that can bear alkyl substituents, preferably said alkyl substituents are C_1 - C_{10} -alkyl radicals;

R^{19} , R^{20} and R^{21} are hydrogen atoms or a linear or branched, saturated or unsaturated

C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; with the proviso that at least one R¹⁹, R²⁰ and R²¹ is different from a hydrogen atom;

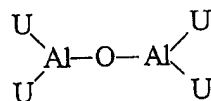
Preferably in the compounds of formula (IV) R²², R²³, R²⁴, R²⁵, R²⁶, R²⁷ and R²⁸ are hydrogen atoms; R¹⁸ is a hydrogen atom or a C₁-C₂₀ alkyl radical; R¹⁹, R²⁰, R²¹ are a C₁-C₂₀ alkyl radical; more preferably they are methyl groups.

Metallocene compounds of formula (I) are well known in the art. In particular compounds of class (1) and (2) have been described in WO 01/47939; compounds belonging to class (3) have been described in EP 537 130.

Alumoxanes used as component B) can be obtained by reacting water with an organo-aluminium compound of formula H_jAlU_{3-j} or H_jAl₂U_{6-j}, where U substituents, same or different, are hydrogen atoms, halogen atoms, C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl or or C₇-C₂₀-arylalkyl radical, optionally containing silicon or germanium atoms with the proviso that at least one U is different from halogen, and j ranges from 0 to 1, being also a non-integer number. In this reaction the molar ratio of Al/water is preferably comprised between 1:1 and 100:1.

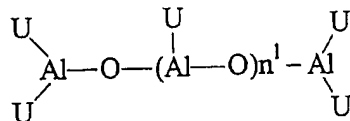
The molar ratio between aluminium and the metal of the metallocene generally is comprised between about 10:1 and about 20000:1, and more preferably between about 100:1 and about 5000:1.

The alumoxanes used in the catalyst according to the invention are considered to be linear, branched or cyclic compounds containing at least one group of the type:

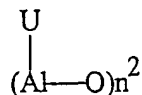


wherein the substituents U, same or different, are described above.

In particular, alumoxanes of the formula:



can be used in the case of linear compounds, wherein n¹ is 0 or an integer from 1 to 40 and the substituents U are defined as above, or alumoxanes of the formula:



can be used in the case of cyclic compounds, wherein n^2 is an integer from 2 to 40 and the U substituents are defined as above.

Examples of alumoxanes suitable for use according to the present invention are methylalumoxane (MAO), tetra-(isobutyl)alumoxane (TIBAO), tetra-(2,4,4-trimethyl-pentyl)alumoxane (TIOAO), tetra-(2,3-dimethylbutyl)alumoxane (TDMBAO) and tetra-(2,3,3-trimethylbutyl)alumoxane (TTMBAO).

Particularly interesting cocatalysts are those described in WO 99/21899 and in WO01/21674 in which the alkyl and aryl groups have specific branched patterns.

Non-limiting examples of aluminium compounds according to WO 99/21899 and WO01/21674 are:

tris(2,3,3-trimethyl-butyl)aluminium, tris(2,3-dimethyl-hexyl)aluminium, tris(2,3-dimethyl-butyl)aluminium, tris(2,3-dimethyl-pentyl)aluminium, tris(2,3-dimethyl-heptyl)aluminium, tris(2-methyl-3-ethyl-pentyl)aluminium, tris(2-methyl-3-ethyl-hexyl)aluminium, tris(2-methyl-3-ethyl-heptyl)aluminium, tris(2-methyl-3-propyl-hexyl)aluminium, tris(2-ethyl-3-methyl-butyl)aluminium, tris(2-ethyl-3-methyl-pentyl)aluminium, tris(2,3-diethyl-pentyl)aluminium, tris(2-propyl-3-methyl-butyl)aluminium, tris(2-isopropyl-3-methyl-butyl)aluminium, tris(2-isobutyl-3-methyl-pentyl)aluminium, tris(2,3,3-trimethyl-pentyl)aluminium, tris(2,3,3-trimethyl-hexyl)aluminium, tris(2-ethyl-3,3-dimethyl-butyl)aluminium, tris(2-ethyl-3,3-dimethyl-pentyl)aluminium, tris(2-isopropyl-3,3-dimethyl-butyl)aluminium, tris(2-trimethylsilyl-propyl)aluminium, tris(2-methyl-3-phenyl-butyl)aluminium, tris(2-ethyl-3-phenyl-butyl)aluminium, tris(2,3-dimethyl-3-phenyl-butyl)aluminium, tris(2-phenyl-propyl)aluminium, tris[2-(4-fluoro-phenyl)-propyl]aluminium, tris[2-(4-chloro-phenyl)-propyl]aluminium, tris[2-(3-isopropyl-phenyl)-propyl]aluminium, tris(2-phenyl-butyl)aluminium, tris(3-methyl-2-phenyl-butyl)aluminium, tris(2-phenyl-pentyl)aluminium, tris[2-(pentafluorophenyl)-propyl]aluminium, tris[2,2-diphenyl-ethyl]aluminium and tris[2-phenyl-2-methyl-propyl]aluminium, as well as the corresponding compounds wherein one of the hydrocarbyl groups is replaced with a hydrogen atom, and those wherein one or two of the hydrocarbyl groups are replaced with an isobutyl group.

Amongst the above aluminium compounds, trimethylaluminium (TMA), triisobutylaluminium (TIBAL), tris(2,4,4-trimethyl-pentyl)aluminium (TIOA), tris(2,3-dimethylbutyl)aluminium

(TDMBA) and tris(2,3,3-trimethylbutyl)aluminium (TTMBA) are preferred.

Non-limiting examples of compounds able to form an alkylmetallocene cation are compounds of formula D^+E^- , wherein D^+ is a Brønsted acid, able to donate a proton and to react irreversibly with a substituent X of the metallocene of formula (I) and E^- is a compatible anion, which is able to stabilize the active catalytic species originating from the reaction of the two compounds, and which is sufficiently labile to be able to be removed by an olefinic monomer. Preferably, the anion E^- comprises of one or more boron atoms. More preferably, the anion E^- is an anion of the formula $BAr_4^{(-)}$, wherein the substituents Ar which can be identical or different are aryl radicals such as phenyl, pentafluorophenyl or bis(trifluoromethyl)phenyl. Tetrakis-pentafluorophenyl borate is particularly preferred examples of these compounds are described in WO 91/02012. Moreover, compounds of the formula BAr_3 can conveniently be used. Compounds of this type are described, for example, in the published International patent application WO 92/00333. Other examples of compounds able to form an alkylmetallocene cation are compounds of formula BAr_3P wherein P is a substituted or unsubstituted pyrrol radicals. . These compounds are described in WO01/62764. Other examples of cocatalyst can be found in EP 775707 and DE 19917985. Compounds containing boron atoms can be conveniently supported according to the description of DE-A-19962814 and DE-A-19962910. All these compounds containing boron atoms can be used in a molar ratio between boron and the metal of the metallocene comprised between about 1:1 and about 10:1; preferably 1:1 and 2.1; more preferably about 1:1.

Non limiting examples of compounds of formula D^+E^- are:

Triethylammoniumtetra(phenyl)borate,
 Tributylammoniumtetra(phenyl)borate,
 Trimethylammoniumtetra(tolyl)borate,
 Tributylammoniumtetra(tolyl)borate,
 Tributylammoniumtetra(pentafluorophenyl)borate,
 Tributylammoniumtetra(pentafluorophenyl)aluminate,
 Tripropylammoniumtetra(dimethylphenyl)borate,
 Tributylammoniumtetra(trifluoromethylphenyl)borate,
 Tributylammoniumtetra(4-fluorophenyl)borate,
 N,N-Dimethylaniliniumtetra(phenyl)borate,
 N,N-Diethylaniliniumtetra(phenyl)borate,
 N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)borate,
 N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)aluminate,

Di(propyl)ammoniumtetrakis(pentafluorophenyl)borate,
 Di(cyclohexyl)ammoniumtetrakis(pentafluorophenyl)borate,
 Triphenylphosphoniumtetrakis(phenyl)borate,
 Triethylphosphoniumtetrakis(phenyl)borate,
 Diphenylphosphoniumtetrakis(phenyl)borate,
 Tri(methylphenyl)phosphoniumtetrakis(phenyl)borate,
 Tri(dimethylphenyl)phosphoniumtetrakis(phenyl)borate,
 Triphenylcarbeniumtetrakis(pentafluorophenyl)borate,
 Triphenylcarbeniumtetrakis(pentafluorophenyl)aluminate,
 Triphenylcarbeniumtetrakis(phenyl)aluminate,
 Ferroceniumtetrakis(pentafluorophenyl)borate,
 Ferroceniumtetrakis(pentafluorophenyl)aluminate.
 Triphenylcarbeniumtetrakis(pentafluorophenyl)borate,
 N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)borate.

Organic aluminum compounds used as compound C) are those of formula H_jAlU_{3-j} or $H_jAl_2U_{6-j}$ described above.

The catalysts of the present invention can also be supported on an inert carrier. This is achieved by depositing the metallocene compound A) or the product of the reaction thereof with the component B), or the component B) and then the metallocene compound A) on an inert support such as, for example, silica, alumina, Al-Si, Al-Mg mixed oxides, magnesium halides, styrene/divinylbenzene copolymers, polyethylene or polypropylene. The supportation process is carried out in an inert solvent such as hydrocarbon for example toluene, hexane, pentane or propane and at a temperature ranging from 0°C to 100°C, preferably the process is carried out at a temperature ranging from 25°C to 90°C or the process is carried out at room temperature.

A suitable class of supports which can be used is that constituted by porous organic supports functionalized with groups having active hydrogen atoms. Particularly suitable are those in which the organic support is a partially crosslinked styrene polymer. Supports of this type are described in European application EP-633272.

Another class of inert supports particularly suitable for use according to the invention is that of polyolefin porous prepolymers, particularly polyethylene.

A further suitable class of inert supports for use according to the invention is that of porous magnesium halides such as those described in International application WO 95/32995.

The solid compound thus obtained, in combination with the further addition of the alkylaluminium compound either as such or prereacted with water if necessary, can be usefully employed in the gas-phase polymerization.

With the process of the present invention it is possible to obtain a 1-butene polymer having high molecular weight and in high yields.

Another object of the present invention is a 1-butene homopolymer obtainable with the process of the present invention in particular when compounds of class 1 or 2 are used, having the following characteristics:

- $65 < \text{mm} < 100$; preferably $75 < \text{mm} < 100$; even more preferably $80 < \text{mm} < 100$;
- intrinsic viscosity (I.V.) > 0.45 ; preferably ≥ 0.5 ; more preferably > 0.7 .
- 4,1 insertions (regioerrors) $< 0.19\%$; preferably $< 0.1\%$;
- an extractable content in boiling diethylether $< 2\%$; preferably $< 1\%$.

Preferably the 1-butene homopolymer of the present invention does not have 4,1 insertions (regioerrors) detectable with a 400 MHz spectrometer operating at 100.61 MHz. Preferably the 1-butene homopolymer of the present invention has isotactic pentads (mmmm) $\geq 90\%$ more preferably $\geq 93\%$.

More preferably the 1-butene homopolymer of the present invention does not have extractable content in boiling diethylether.

Furthermore the 1-butene homopolymer object of the present invention satisfies the following formula:

$$(\text{mmmm}) > 90 - 2 \times \text{rr}$$

wherein

mmmm is the value of the isotactic pentads and rr is the value of the syndiotactic triads calculated with 400 MHz spectrometer operating at 100.61 MHz.

Furthermore the 1-butene homopolymers of the present invention are endowed with a flexural modulus value (ASTM D-790) comprised between 150 and 300 Mpa. This value of the modulus in conjunction with the relatively high melting point render the 1-butene homopolymers of the present invention useful for advantageously replacing the 1-butene copolymers that at equivalent melting point show a lower flexural modulus.

The polymerization process of the present invention can be carried out in liquid phase, optionally in the presence of an inert hydrocarbon solvent, or in gas phase. Said hydrocarbon solvent can be either aromatic (such as toluene) or aliphatic (such as propane, hexane, heptane,

isobutane, cyclohexane and 2,2,4-trimethylpentane).

The polymerization temperature preferably ranges from 0°C to 250°C; preferably comprised between 20°C and 150°C and, more particularly between 40°C and 90°C;

Generally, the polymers of the present invention are endowed with a narrow molecular weight distribution. The molecular weight distribution is represented by the ratio M_w/M_n which, for the polymers of the present invention, when the metallocene used is a pure isomer, is generally lower than 4, preferably lower than 3.5 and, more preferably, lower than 3.

The molecular weight distribution can be varied by using mixtures of different metallocene compounds or by carrying out the polymerization in several stages which differ as to the polymerization temperature and/or the concentrations of the molecular weight regulators and/or the monomers concentration. Moreover by carrying out the polymerization process by using a combination of two different metallocene compounds of formula (I) a polymer endowed with a broad melting is produced.

The polymerization yield depends on the purity of the transition metal organometallic catalyst compound (A) in the catalyst, therefore, said compound can be used as such or can be subjected to purification treatments before use.

The following examples are for illustrative purpose and do not intend to limit the scope of the invention.

EXAMPLES

Experimental section

The intrinsic viscosity (I.V.) was measured in tetrahydronaphtalene (THN) at 135°C.

The melting points of the polymers (T_m) were measured by Differential Scanning Calorimetry (D.S.C.) on an Perkin Elmer DSC-7 instrument, according to the standard method. A weighted sample (5-10 mg) obtained from the polymerization was sealed into aluminum pans and heated at 200°C with a scanning speed corresponding to 20°C/minute. The sample was kept at 200°C for 5 minutes to allow a complete melting of all the crystallites. Successively, after cooling to 0°C with a scanning speed corresponding to 20°C/minute, the peak temperature was taken as crystallization temperature (T_c). After standing 5 minutes at 0°C, the sample was heated for the second time at 200°C with a scanning speed corresponding to 20°C/min. In this second heating run, the peak temperature was taken as the melting temperature (T_m) and the area as global melting enthalpy (ΔH_f).

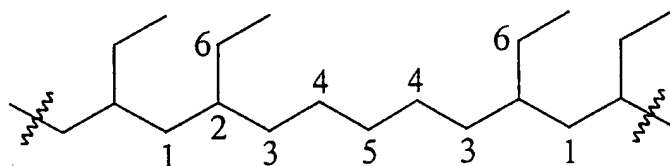
The molecular weight distribution was determined on a WATERS 150 C using the following

chromatographic conditions:

Columns: 3x SHODEX AT 806 MS; 1x SHODEX UT 807; 1x SHODEX AT-G;
 Solvent: 1,2,4 trichlorobenzene (+ 0.025% 2,6-Di-tert.Butyl-4-Methyl-Phenol);
 Flow rate: 0.6 - 1 ml/min;
 Temperature: 135 °C;
 Detector: INFRARED AT $\lambda \approx 3.5 \mu\text{m}$;
 Calibration: Universal Calibration with PS-Standards.

^{13}C -NMR spectra were acquired on a DPX-400 spectrometer operating at 100.61 MHz in the Fourier transform mode at 120 °C. The peak of the 2B_2 carbon (nomenclature according to Carman, C. J.; Harrington, R. A.; Wilkes, C. E. *Macromolecules* 1977, 10, 535) was used as internal reference at 27.73. The samples were dissolved in 1,1,2,2-tetrachloroethane- d_2 at 120 °C with a 8% wt/v concentration. Each spectrum was acquired with a 90° pulse, 15 seconds of delay between pulses and CPD (waltz16) to remove 1H - ^{13}C coupling. About 3000 transients were stored in 32K data points using a spectral window of 6000 Hz. Assignments of 4,1 insertion were made according to Busico (V. Busico, R. Cipullo, A. Borriello, *Macromol. Rapid. Commun.* 1995, 16, 269-274)

The content of 4,1 insertions was calculated as follows: $4,1 \text{ units} = 0.5 \times I_4 \times 100 / (I_2 + I_4)$



4,1-sequence

Preparation of catalyst components

isopropylidene(3-tertbutyl-1-cyclopentadienyl)(9-fluorenyl) zirconium dichloride (A-1) was prepared according to EP 537130. Dimethylsilyl{(1-indenyl)-7-(2,5-dimethyl-cyclopenta[1,2-b:4,3-b']-dithiophene)} zirconium dichloride (A-2); dimethylsilyl{(2-methyl-1-indenyl)-7-(2,5-dimethyl-cyclopenta[1,2-b:4,3-b']-dithiophene)} zirconium dichloride (A-3) and dimethylsilyl{(2-methylcyclopenta[a]naphthalene)-7-(2,5-dimethylcyclopenta[1,2-b:4,3-b']-dithiophene)} zirconium dichloride (A-4) were prepared according to PCT/EP00/13191. rac dimethylsilylbis(2-methyl-4-phenyl-indenyl) zirconium dichloride (A-5) was prepared

according to USP 5,786,432. rac dimethylsilylbis(2-methyl-4-5-benzoindenyl) zirconium dichloride (A-6) was prepared according to USP 5,932,669.

The cocatalyst methylalumoxane (MAO) was a commercial product which was used as received (Witco AG, 10 %wt/vol toluene solution, 1.7 M in Al).

Polymerization examples 1-4 and comparative examples 5-6

The cocatalyst methylalumoxane (MAO) was a commercial product which was used as received (Witco AG, 10 %wt/vol toluene solution, 1.7 M in Al). The catalyst mixture was prepared by dissolving the desired amount of the metallocene with the proper amount of the MAO solution, (Al/Zr ratio = 1000) obtaining a solution which was stirred for 10 min at ambient temperature before being injected into the autoclave.

Polymerization (general procedure)

4 mmol of Al(*i*-Bu)₃ (as a 1M solution in hexane) and 712 g of 1-butene were charged at room temperature in a 2.5-L jacketed stainless-steel autoclave, equipped with magnetically driven stirrer and a 35-mL stainless-steel vial, connected to a thermostat for temperature control, previously purified by washing with an Al(*i*-Bu)₃ solution in hexanes and dried at 50°C in a stream of nitrogen. The autoclave was then thermostatted at the polymerization temperature, and then the toluene solution containing the catalyst/cocatalyst mixture was injected in the autoclave by means of nitrogen pressure through the stainless-steel vial, and the polymerization carried out at constant temperature for 1 hour. The polymerization was stopped by pressurizing CO into the reactor. After venting the unreacted monomer and cooling the reactor to room temperature, the polymer was dried under reduced pressure at 60 °C.

The polymerization conditions and the characterization data of the obtained polymers are reported in Table 1

Diethyl ether solubles

Samples of 5 g of 1-butene polymer obtained according to polymerization examples 1-4 was subjected to Soxhlet extraction with diethyl ether for 6 hours. The extracts was evaporated. No residues of polymer were found.

Characterization of the polymer obtained in example 3

Samples of polymer obtained from example 3 and a 1-butene ethylene copolymer (4.7% by mol of ethylene content) sold by Basell (grade DP – 8310) were ground in an electric mill with liquid nitrogen in order to achieve the right size to feed them in a Brabender® mixer

chamber. The ground samples were mixed in a Brabender[®] chamber with 1% 2,6-di-*t*-butyl-4-methyl phenol (BHT) at 200°C and then transformed in a 4.0 mm thick plaques through compression molding at 200°C.

The 4.0 mm thick plaques were submitted to the flexural modulus determination according to ISO 178 method. The results are reported in table 2. From table 2 clearly results that the commercial copolymer has the same melting point of the polymer obtained in example 3 but a considerably lower Flexural modulus.

Table 1

Ex	metall	mg	Al _(MAO) /Zr	T _{pol}	t (min)	Yield (g)	Activity kg/(g _{cat} ·h)	I.V. (dL/g)	M _w /M _n	T _m (II) °C	ΔH _f (II) J/g
1	A-1	4	1000	60	30	46.4	23.2	0.5	n.a.	100	33
2	A-2	4	1000	60	15	79.4	79.4	0.5	2.25	67	36
3	A-3	4	1000	60	60	249.4	62.4	0.9	2.13	77	13
4	A-4	4	1000	60	30	108.5	54.2	0.8	2.56	91	27
5*	A-5	4	1000	60	30	39.5	9.9	0.9	2.12	105	33
6*	A-6	4	1000	60	60	17.5	4.4	1.1	n.a.	n.a.	n.a.

* comparative; n.d.=not detectable; n.a.=not available

Table 1 (continued)

Ex	mmmm	mm	mmrr + rmmr	rr	90-2rr	regioerrors 4,1 insertions
1	98	98.7	0.9	0	90	n.d.
2	86	91.3	5.8	2.9	84.2	n.d.
3	87	92.2	5.2	2.6	84.8	n.d.
4	94	96.6	2.2	1.1	87.8	n.d.
5*	n.a.	≈100	n.a.	n.a.	n.a.	0.4
6*	n.a.	99.2	n.a.	n.a.	n.a.	1

* comparative; n.d.=not detectable; n.a.=not available

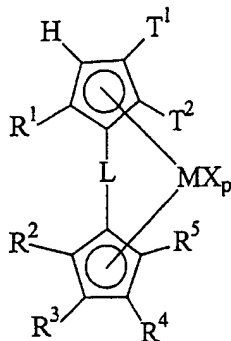
Table 2

Property	DP-8310	Example 3
T _m (II) (°C)	83.8	84.1
M _w /M _n	5.0	2.13
I.V. (dL/g)	1.50	0.9
Flexural modulus (Mpa)	73	250

CLAIMS

1. A process for polymerizing 1-butene comprising contacting under polymerization conditions 1-butene, optionally from 0 to 30% by mol of ethylene, propylene or an alpha olefin of formula $\text{CH}_2=\text{CHT}$ wherein T is a $\text{C}_3\text{-C}_{10}$ alkyl group, in the presence of a catalyst system obtainable by contacting:

(A) a metallocene compound having the following formula (I)



(I)

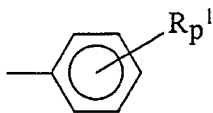
wherein:

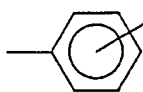
X, equal to or different from each other, is a hydrogen atom, a halogen atoms or R, OR, OR'O, OSO_2CF_3 , OCOR, SR, NR_2 or PR_2 group, wherein R is a linear or branched, saturated or unsaturated $\text{C}_1\text{-C}_{20}$ -alkyl, $\text{C}_3\text{-C}_{20}$ -cycloalkyl, $\text{C}_6\text{-C}_{20}$ -aryl, $\text{C}_7\text{-C}_{20}$ -alkylaryl or $\text{C}_7\text{-C}_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; and the R' is a $\text{C}_1\text{-C}_{20}$ -alkylidene, $\text{C}_6\text{-C}_{20}$ -arylidene, $\text{C}_7\text{-C}_{20}$ -alkylarylidene, or $\text{C}_7\text{-C}_{20}$ -arylalkylidene radical.

p is 1 or 2 being equal to the oxidation state of the metal M minus 2;

R^1 is a hydrogen atom or a linear or branched, saturated or unsaturated $\text{C}_1\text{-C}_{20}$ -alkyl, $\text{C}_3\text{-C}_{20}$ -cycloalkyl, $\text{C}_6\text{-C}_{20}$ -aryl, $\text{C}_7\text{-C}_{20}$ -alkylaryl, or $\text{C}_7\text{-C}_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

R^2 with R^3 , and R^4 with R^5 , form a 5 or 6 membered unsaturated rings optionally containing heteroatoms belonging to groups 13 -16 of the Periodic Table of the Elements and optionally bearing alkyl substituents, preferably said alkyl substituents are $\text{C}_1\text{-C}_{10}$ -alkyl radicals;



T^1 is $C(R^6)_3$ or  wherein R is a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; p^1 ranges from 0 to 5; and R^6 , equal to or different from each other, are hydrogen atoms or a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; with the proviso that at least one R^6 is different from a hydrogen atom;

T^2 is a hydrogen atom or a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

T^1 and T^2 can also join to form a saturated or unsaturated, condensed 5 or 6 membered ring optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements; said ring can be substituted;

L is a divalent bridging group selected from the group consisting of CR^7_2 , SiR^7_2 , $(CR^7_2)_2$ and $(SiR^7_2)_2$ radicals, wherein R^7 equal to or different from each other are hydrogen atoms or a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; optionally two R^7 groups can also form an aliphatic ring having 3 to 8 atoms which can bear alkyl substituents, preferably said alkyl substituents are C_1 - C_{10} -alkyl radicals;

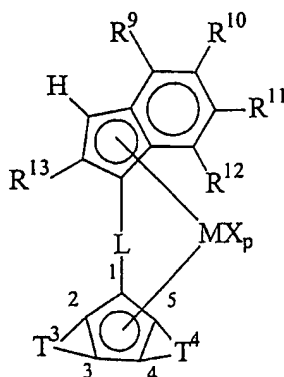
M is an atom of a transition metal selected from those belonging to group 3, 4, or to the lanthanide or actinide groups in the Periodic Table of the Elements (new IUPAC version); and

(B) an alumoxane and/or a compound capable of forming an alkyl metallocene cation.

2. The process according to claim 1 wherein the catalyst system is obtained by further contacting the components (A) and (B) with:

(C) an organo aluminum compound.

3. The process according to claims 1 or 2 wherein in the metallocene of formula (I) L is CR^7_2 or SiR^7_2 ; wherein R^7 is a hydrogen atom or a methyl or phenyl radical; M is zirconium or hafnium; X is a hydrogen atom, a halogen atom or a $\text{OR}'\text{O}$ or R group wherein R is a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements and R' is a divalent radical selected from the group consisting of C_1 - C_{20} -alkylidene, C_6 - C_{20} -arylidene, C_7 - C_{20} -alkylarylidene, and C_7 - C_{20} -arylalkylidene radicals.
4. The process according to anyone of claims 1-3 wherein the metallocene has formula (II):



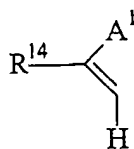
(II)

wherein:

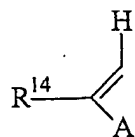
L, M, X and p have the meaning indicated in claims 1 or 2;

R^{13} is a hydrogen atom or a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; R^9 , R^{10} , R^{11} and R^{12} are hydrogen atoms or linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radicals, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; R^9 , R^{10} , R^{11} and R^{12} can also form one or more 5 or 6 membered saturated or unsaturated ring optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements, said ring can bear alkyl substituents;

T^3 and T^4 are moieties of formula (IIa) or (IIb):



(IIa)



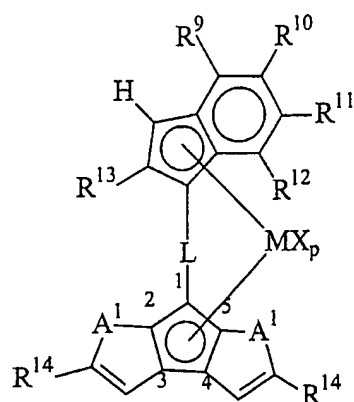
(IIb)

wherein

when T³ and T⁴ are moieties of formula (IIa) A¹ bonds to the cyclopentadienyl group in position 2 and 5;

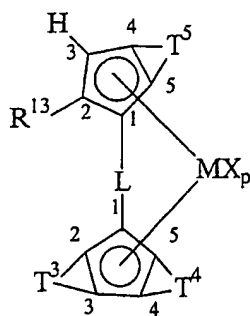
when T³ and T⁴ are moieties of formula (IIb) A¹ bonds to the cyclopentadienyl group in position 3 and 4;

- A¹ is a sulphur atom(S), a oxygen atom (O), or a NR, PR, or CR¹⁵ group; wherein R is a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; R¹⁴ is a hydrogen atom or a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;
5. The process according to claim 4 wherein R¹³ is a linear or branched C₁-C₂₀ alkyl radical; R⁹ is a C₁-C₂₀ alkyl or C₆-C₂₀ aryl radical; R¹⁰, R¹¹ and R¹² are hydrogen atoms; in the moiety (IIa) A¹ is sulfur and in the moiety (IIb) A¹ is NR wherein R is defined as in claim 4; R¹⁴ is a C₁-C₂₀ alkyl radical.
 6. The process according to claims 4 or 5 wherein the metallocene compound has formula (IIc)



(IIc)

- wherein R^9 , R^{10} , R^{11} , R^{12} , R^{13} , R^{14} , A^1 , L , M , X , and p have the meaning described in claims 4 or 5.
7. The process according to anyone of claims 1-3 wherein the metallocene has formula (III):

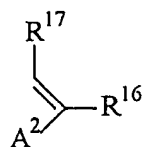


(III)

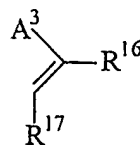
wherein:

T^3 , T^4 , R^{13} , M , X , p and L have the meaning described in anyone of claims 4 or 5;

T^5 is a moiety of formula (IIIa) or (IIIb)



(IIIa)

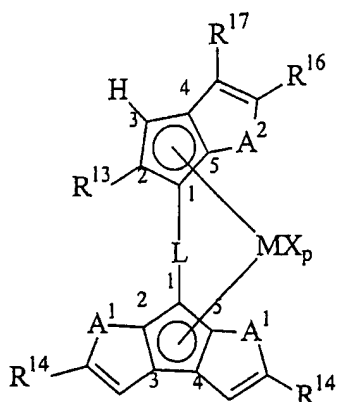


(IIIb)

wherein in the moiety of formula (IIIa) A^2 bonds to the cyclopentadienyl group in position 5; in the moiety of formula (IIIb) A^3 bonds to the cyclopentadienyl group in position 4;

A² is a sulphur atom (S), an oxygen atom (O), or a CR¹⁵ group; wherein R¹⁵ has the meaning described in claim 3; R¹⁶ is a hydrogen atom or a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; R¹⁷ is a hydrogen atom or a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; R¹⁷ and R¹⁶ can also join to form a 5 or 6 membered aliphatic or aromatic ring; said ring can bear alkyl substituents, preferably said alkyl substituents are C₁-C₁₀-alkyl radicals; A³ is a NR group or a CR¹⁵ group wherein R is a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; and R¹⁵ has the meaning described in claims 3 or 4.

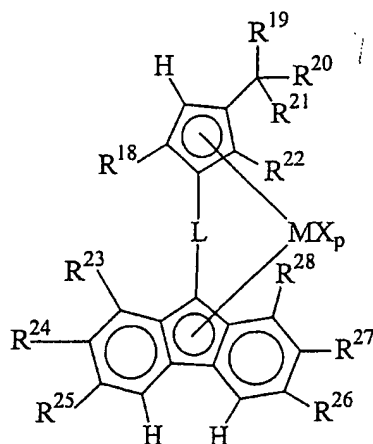
8. The process according to claim 7 wherein R¹⁶ is a C₁-C₂₀ alkyl radical; R¹⁷ is a C₁-C₂₀ alkyl or a C₆-C₂₀ alkylaryl radical; A² is sulfur atom; y A³ is a NR group, wherein R is a linear or branched, saturated or unsaturated C₁-C₂₀-alkyl, C₃-C₂₀-cycloalkyl, C₆-C₂₀-aryl, C₇-C₂₀-alkylaryl, or C₇-C₂₀-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements.
9. The process according to claims 7 or 8 wherein the metallocene compound has formula (IIIc):



(IIIc)

wherein R^{13} , R^{14} , R^{16} , R^{17} , A^1 , A^2 , L , M , X , and p have the meaning described in claims 7 or 8.

10. The process according to anyone of claims 1-3 wherein the metallocene has formula (IV):



(IV)

Wherein M , L , X and p have the meaning described in claims 1 or 2;

R^{18} , R^{22} , R^{23} , R^{24} , R^{25} , R^{26} , R^{27} and R^{28} are hydrogen atoms or a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; or two or more adjacent R^{23} , R^{24} , R^{25} , R^{26} , R^{27} , and R^{28} can form one or more aliphatic or aromatic C_4 - C_8 rings that can bear alkyl substituents, preferably said alkyl substituents are C_1 - C_{10} -alkyl radicals;

R^{19} , R^{20} and R^{21} are hydrogen atoms or a linear or branched, saturated or unsaturated C_1 - C_{20} -alkyl, C_3 - C_{20} -cycloalkyl, C_6 - C_{20} -aryl, C_7 - C_{20} -alkylaryl, or C_7 - C_{20} -arylalkyl radical,

optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; with the proviso that at least one R^{19} , R^{20} and R^{21} is different from a hydrogen atom.

11. The process according to claim 10 wherein R^{22} , R^{23} , R^{24} , R^{25} , R^{26} , R^{27} and R^{28} are hydrogen atoms; R^{18} is a hydrogen atom or a C_1 - C_{20} alkyl radical; R^{19} , R^{20} , R^{21} are C_1 - C_{20} alkyl radicals.
12. The 1-butene homopolymer having the following characteristics:
 - (mmmm)>90-2x rr;
 - intrinsic viscosity (I.V.) > 0.45;
 - 4,1 insertions (regioerrors) < 0.19%; and
 - an extractable content in boiling diethylether < 2%;wherein
mmmm is the value of the isotactic pentads and rr is the value of the syndiotactic triads.
13. A 1-butene homopolymer having the following characteristics:
 - isotactic pentads (mmmm) \geq 90%;
 - intrinsic viscosity (I.V.) > 0.45;
 - 4,1 insertions (regioerrors) < 0.19%; and
 - an extractable content in boiling diethylether < 2%.
14. The 1-butene homopolymer according to claims 12 or 13 having a flexural modulus value (ASTM D-790) comprised between 150 and 300 Mpa.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 02/12731

A. CLASSIFICATION OF SUBJECT MATTER IPC 7 C08F10/08 C08F4/642		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC 7 C08F		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the International search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data, PAJ, CHEM ABS Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 52955 A (RIEGER BERNHARD) 21 October 1999 (1999-10-21)	1-11
A	claims 1,5,11-17; figures; examples	12-14
X	DE 199 62 910 A (TARGOR GMBH) 5 July 2001 (2001-07-05) cited in the application page 12, line 38 -page 18, line 22 page 20, line 36 - line 37; claims	1-11
X	WO 99 02569 A (UNIV LELAND STANFORD JUNIOR ;WAYMOUTH ROBERT M (US); LECLERC MARGR) 21 January 1999 (1999-01-21) page 3, line 23 -page 7, line 2 page 10, line 26 -page 11, line 3; claims; examples	1-11
	--- -/--	
<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex.		
* Special categories of cited documents : *A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the International filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the International filing date but later than the priority date claimed *T* later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art *&* document member of the same patent family		
Date of the actual completion of the International search 11 March 2003		Date of mailing of the international search report 20/03/2003
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3018		Authorized officer Kaumann, E

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/12731

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 180 732 B1 (EWEN JOHN A) 30 January 2001 (2001-01-30) column 13, line 28 - line 51 column 14, line 37 - line 42; claims ---	1-11
X	EP 0 786 466 A (TOSOH CORP) 30 July 1997 (1997-07-30) page 12, line 46; claims ---	1-11
X	WO 99 45043 A (MONTELL TECHNOLOGY COMPANY BV) 10 September 1999 (1999-09-10) cited in the application the whole document ---	12-14
X	JP 60 262804 A (MITSUI SEKIYU KAGAKU KOGYO KK) 26 December 1985 (1985-12-26) abstract ---	12-14
X	& PATENT ABSTRACTS OF JAPAN , 20 May 1986 (1986-05-20) & JP 60 262804 A (MITSUI PETROCHEMICAL IND), 26 December 1985 (1985-12-26) abstract ---	12-14
A	WO 01 47939 A (RESONI LUIGI ;GUIDOTTI SIMONA (IT); BASSELL TECHNOLOGY COMPANY B V) 5 July 2001 (2001-07-05) cited in the application claims -----	1-11

INTERNATIONAL SEARCH REPORT

...formation on patent family members

Int'l Application No

PCT/EP 02/12731

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 9952955	A	21-10-1999	DE 19816154 A1	21-10-1999
			AT 220074 T	15-07-2002
			AU 3420999 A	01-11-1999
			AU 3706899 A	01-11-1999
			BR 9909533 A	12-12-2000
			BR 9909534 A	07-05-2002
			CN 1296496 T	23-05-2001
			CN 1296500 T	23-05-2001
			DE 69902032 D1	08-08-2002
			DE 69902032 T2	30-01-2003
			DK 1070087 T3	22-07-2002
			WO 9952950 A1	21-10-1999
			WO 9952955 A1	21-10-1999
			EP 1178057 A2	06-02-2002
			EP 1070087 A1	24-01-2001
			EP 1070089 A1	24-01-2001
			ES 2178887 T3	01-01-2003
			JP 2002511499 T	16-04-2002
			JP 2002511503 T	16-04-2002
			PT 1070087 T	31-10-2002
DE 19962910	A	05-07-2001	DE 19962910 A1	05-07-2001
			WO 0148035 A2	05-07-2001
			EP 1250363 A2	23-10-2002
			US 2003013913 A1	16-01-2003
WO 9902569	A	21-01-1999	AU 8491298 A	08-02-1999
			WO 9902569 A1	21-01-1999
			US 6184317 B1	06-02-2001
			US 6380125 B1	30-04-2002
US 6180732	B1	30-01-2001	US 5631202 A	20-05-1997
EP 0786466	A	30-07-1997	EP 0786466 A1	30-07-1997
			JP 10226694 A	25-08-1998
			US 6316558 B1	13-11-2001
WO 9945043	A	10-09-1999	AU 744327 B2	21-02-2002
			AU 3143199 A	20-09-1999
			BR 9904849 A	25-07-2000
			CN 1256698 T	14-06-2000
			WO 9945043 A1	10-09-1999
			EP 0980396 A1	23-02-2000
			JP 2001523302 T	20-11-2001
			NO 995386 A	04-11-1999
			TR 9902698 T1	23-10-2000
			US 6306996 B1	23-10-2001
JP 60262804	A	26-12-1985	JP 1849211 C	07-06-1994
			JP 5059922 B	01-09-1993
WO 0147939	A	05-07-2001	AU 2843301 A	09-07-2001
			BR 0010277 A	15-01-2002
			CN 1348459 T	08-05-2002
			WO 0147939 A1	05-07-2001
			EP 1157027 A1	28-11-2001
			US 2003036612 A1	20-02-2003